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Nuclear Effect on the Nucleon Structure Functions and High P_T Jet Production in p-Fe Collisions

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Using the empirical formula of $F_2^N(\mathrm{Fe})/F_2^N(\mathrm{D})$ found by us and generalizing the method used by CERN, UA1 Collaboration in analyzing the process $p + \bar{p} \to 2\mathrm{jet} + X$, a simple calculating method on $p + \mathrm{Fe} \to 2\mathrm{jet} + X$ process is presented. Our results are compared with the experimental data and the other theoretical calculations. Some results will be checked by future experiments.

1. NUCLEAR EFFECT ON NUCLEON STRUCTURE FUNCTIONS

The nuclear effect on nucleon structure functions includes shadowing effect, Fermi motion effect and EMC effect [1-3], We found that nuclear effect of Fe nucleus can be represented by the following empirical formula:

$$R(x) = F_2^N(\mathrm{Fe})/F_2^N(D)$$
$$= 1 + \frac{1}{10}\,[1.2^{(X/0.54)^4}(1.56 - x) \times \cos 2\pi(x - 0.06)]. \qquad (1)$$

Fig. 1 shows that formula (1) fits the data better than the other theoretical curves [4-6]. Although we have not yet given a theoretical interpretation for the formula, we know that it is convenient by using this formula to calculate nuclear effects in calculation processes involving Fe nucleus, such as $p + \mathrm{Fe} \to 2\mathrm{jet} + X$ and $p + \mathrm{Fe} \to \gamma + X$.

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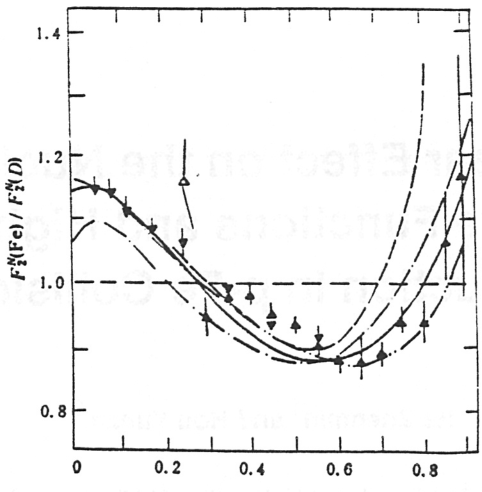

FIG. 1

—··— Staszel et al [4]; ---- Faissner, Kim [5]; —·— Fvrmanski [6]; —— Authors, Data Points Edwards [12]

2. A SIMPLE METHOD TO COMPUTE HIGH P_T JET PRODUCTION IN p-Fe COLLISIONS

Since different subprocesses have a similar θ behavior and the Q^2-dependencies of the structure function $F(x)$ and the QCD coupling constant α_s are weak, by generalizing the method of Refs. [7-9], the differential cross section for high energy p + A→2jet + X process can be approximately factorized as:

$$\frac{d^3\sigma}{dx_1 dx_2 d\cos\theta} = G_{1/p}(x_1) \cdot G_{2/A}(x_2) \cdot d\sigma/d\cos\theta, \tag{2}$$

where parton distribution functions are

$$G_{1/p}(x_1) = F(x_1)/x_1, \tag{3}$$

$$G_{2/A}(x_2) = \begin{cases} F(x_2)/x_2, & \text{(for p(p))} \\ 56F(x_2)/x_2, & \text{(for Fe, NONE.}^{1)}\text{)} \\ 56R(x_2)F(x_2)/x_2, & \text{(for Fe, NE.}^{1)}\text{)} \end{cases} \tag{4}$$

and

$$\begin{aligned} F(x) &= x\left\{g(x) + \frac{4}{9}[q(x) + \bar{q}(x)]\right\} \\ &\simeq 6.2\exp(-9.5x) \end{aligned} \tag{5}$$

1) NE.-including nuclear effect; NONE.-without nuclear effect.

is the overall structure function of proton. The effective parton-parton cross section $d\sigma/d\cos\theta$ in Eq.(2) can be expressed as

$$\frac{d\sigma}{d\cos\theta} = \frac{9}{8}[\pi\alpha_s^2/2x_1x_2s] \times (3+\cos^2\theta)^3(1-\cos^2\theta)^{-2} \tag{6}$$

where θ is the scattering angle in the two-jet center of mass system (cms.) and

$$\alpha_s = 12\pi/[23\ln(Q^2/\Lambda^2)],$$

In the cms., the four momentum conservation gives

$$X_1 = 4P_T^2/x_2S\sin^2\theta = 4Z^2/x_2\sin^2\theta, \quad Z = P_T/\sqrt{s}. \tag{7}$$

Under the condition of Eq.(7) and a given $\sqrt{s}$, by integrating Eq.(2) over x_1, then over x_2, one can get $d\sigma/d\cos\theta(Z, \cos\theta)$ which describes Z (i.e. P_T) distribution of jets at given θ. Then integrating $d\sigma/d\cos\theta(Z, \cos\theta)$ over Z and $\cos\theta$, one can obtain the two-jet total cross section σ.

3. RESULTS AND DISCUSSIONS

Based on the above method we computed the differential cross section and the total cross section of $P_T \geq 2$GeV/c jets production in the processes p + p($\bar{p}$)→2jet + X and p

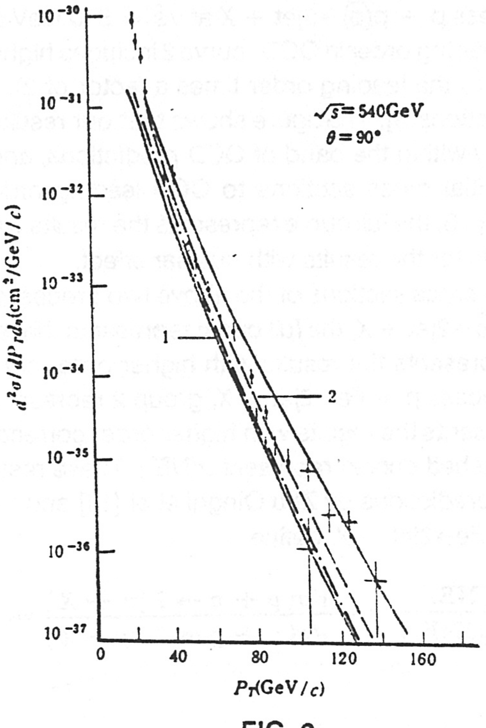

FIG. 2

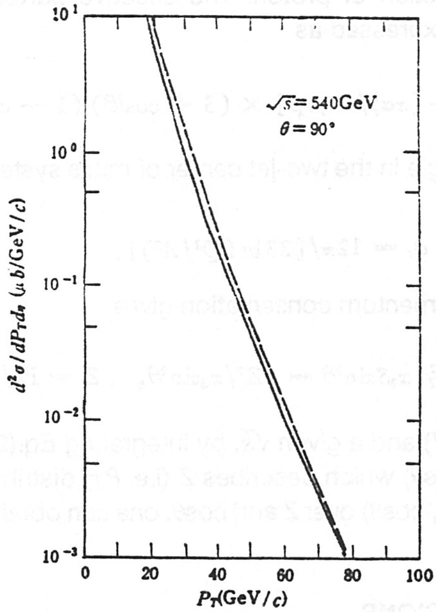

FIG. 3

+ Fe→2jet + X (with or without the nuclear effect)

1) The differential cross sections for jet production around $\theta = 90°$ (pseudorapidity $\eta = -\ln\tan\theta/2 = 0$) in process p + p($\overline{\mathrm{p}}$)→2jet + X at $\sqrt{s}$ = 540 GeV are shown in Fig. 2. Curve 1 is the results of the leading order in QCD, curve 2 includes higher order corrections (as a rule, taking the result to the leading order times a factor of 2). The two full curves define a band of QCD predictions[9]. The figure shows that our results are quite satisfactory. Curve 2 lies completely within the band of QCD predictions, and is consistent with the data[9]. Similar differential cross sections to QCD leading order in process p + Fe→2jet + X are shown in Fig. 3, the full curve represents the results without nuclear effect and the dashed curve stands for the results with nuclear effect.

2) Fig. 4 shows the total cross sections of the above two processes. Curves of group 1 belong to process p + p($\overline{\mathrm{p}}$)→2jet + X, the full curve represents the results to the leading order, the dashed curve represents the results with higher order corrections. Curves of group 2 and 3 belong to process p + Fe→2jet + X, group 2 represents the results to the leading order, group 3 represents the results with higher order corrections; the full curves represent σ (NONE.), the dashed curves represent σ(NE.). These results are qualitatively consistent with the original predictions by Zhu Qingqi et al [10] and Hou Yunzhi [11].

3) For the process p + Fe→2jet + X. define

$$B = \frac{\sigma(\mathrm{NE.})}{\sigma(\mathrm{NONE.})} = \frac{A^{\alpha}\sigma(\mathrm{p}+\mathrm{p}\to 2\ \mathrm{jet}+X)}{A\sigma(\mathrm{p}+\mathrm{p}\to 2\ \mathrm{jet}+X)} = A^{\alpha-1},$$

$$(A = 56) \qquad (8)$$

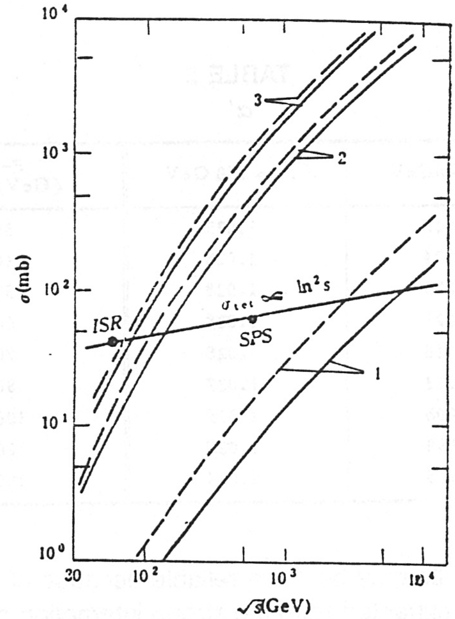

FIG. 4

then

$$\alpha = \ln B / \ln A + 1. \tag{9}$$

Table 1 gives the obtained values of B and α. In general, σ (NE.) is about 10% larger than σ(NONE.), and α is 2–3% larger than 1. For the differential cross sections, define

$$B' = \frac{d^3\sigma/d^3p\,(\text{NE.})}{d^3\sigma/d^3p\,(\text{NONE.})}, \tag{10}$$

and

$$\alpha' = \ln B' / \ln A + 1. \tag{11}$$

Table 2 gives α' values at $\sqrt{s}$ = 100, 500 GeV and θ = 90°. α' is slightly larger than 1 for smaller P_T and slightly smaller than 1 for larger P_T. These results are approximately consistent with the results by Zhu Qingqi et al. [11]

TABLE 1
B and α

$\sqrt{s}$ (GeV)	45	63	100	540	1000	3162.3	10000
B	1.078	1.092	1.104	1.104	1.109	1.115	1.116
α	1.019	1.022	1.025	1.025	1.026	1.027	1.027

TABLE 2

α'

P_T (GeV/C)	$\sqrt{s} = 100$GeV	$\sqrt{s} = 540$ GeV	P_T (GeV/C)	$\sqrt{s} = 540$ GeV
2	1.027	1.029	30	1.020
3	1.024	1.028	40	1.015
4	1.023	1.028	50	1.010
5	1.021	1.028	60	1.004
6	1.018	1.028	70	1.000
8	1.013	1.027	80	0.995
10	1.008	1.026	100	0.987
15	0.994	1.025	120	0.982
20	0.985	1.024	140	0.982

We think that our results may be more reliable because of the use of the nucleon structure function directly extracted from the strong interaction process $p + p(\bar{p}) \to 2$ jet $+ X$.

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